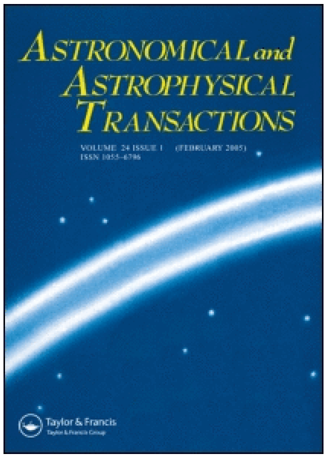

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ON THE POSSIBLE SOURCE OF THE MAGNETIC FIELD DISSIPATION IN THE SOLAR PLASMA

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The oblique interaction of the solar chromospheric rotational or Alfven discontinuity with the transition region, described as a contact discontinuity, is studied. The appearance of the refracted magnetohydrodynamic shock wave going through the solar corona is shown. This wave makes the dissipation of the magnetic field energy inside the coronal plasma possible and may cause explosive events.

Keywords: Magnetohydrodynamic rotational discontinuity; Solar transition region; Dissipation of energy

1 INTRODUCTION

At present there are many data indicating the existence of magnetohydrodynamic (MHD) directional discontinuities both in the solar corona and in the solar wind plasma. Many of these data are connected with so-called pressure-balanced structures (Burlaga, 1995).

Rotational (or Alfven) and tangential discontinuities belong to directional discontinuities, where the first type is the surface of a non-stationary discontinuity, travelling through an unperturbed flow and the second type is at rest relative to the unperturbed region. For both types of MHD discontinuity the integral relations expressing the laws of the conservation are satisfied (Landau and Lifshitz, 1959).

It was shown by Grib et al. (1996) that MHD tangential discontinuities appearing on the boundaries of coronal holes and inside the streamers may help to slow shock dissipative waves to be generated as a result of the refraction of the solar fast shock wave.

2 ANALYSIS

Let us evaluate the possible nonlinear role of the solar rotational discontinuity in the perturbation of plasma inside the transition region from the chromosphere to the solar corona.

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Suppose that from the photospheric side an Alfven wave is traveling along the magnetic flux tube. Its amplitude will increase on the way to the corona and we shall have (Shibata, 1996)

$$\frac{v_\perp}{v_A} \sim \frac{B_\perp}{B} \sim \rho^{1/4} B^{-1}, \tag{1}$$

where v_A is the Alfven velocity, B is the intensity of the magnetic field, ρ is the density and $v_\perp$ is the amplitude.

For unperturbed conditions, $\rho_{tr}/\rho_{ph} \approx 10^{-5}$ and, $B_{tr}/B_{ph} \approx 10^{-2}$, it is possible to find that $v_{\perp tr}/\rho_{\perp ph} \approx 20$ and $(v_\perp/v_A)_{tr}/(v_\perp/v_A)_{ph} \approx 5$.

Thus, a linear MHD Alven wave may become a nonlinear wave or a rotational discontinuity in the case when there is significant widening of a magnetic flux tube.

Therefore, it is reasonable to consider an interaction of a rotational discontinuity A, travelling from the chromospheric downside, with the transition region described in a frame of a contact discontinuity CD:

$$\underset{\rightarrow}{A}\ \underset{\rangle}{CD},$$

where $\underset{\rangle}{CD}$ is a contact discontinuity, across which a plasma density is abruptly changed and a gas-kinetic pressure is constant.

Therefore, we have the relations:

$$\{nkT\} = 0, \quad \{n\} \neq 0, \quad v_n = 0, \quad B_n \neq 0 \tag{2}$$

with $\{A\}$ indicating an abrupt change in the value A across the surface of the discontinuity. v_n is the normal component of the plasma velocity, B_n the normal component of the magnetic field intensity $(H = B)$ and n the concentration of plasma.

For the rotational discontinuity we have the well-known conditions

$$v_n = \frac{\pm B_n}{(4\pi\rho)^{1/2}}, \quad \{n\} \neq 0, \quad B_n \neq 0, \quad \{v_t\} = \frac{\{B_t\}}{(4\pi\rho)^{1/2}}, \tag{3}$$

where v_t and B_t are the tangential components of the plasma velocity and of the intensity of the magnetic field respectively.

The main effect of the rotational discontinuity is rotation of the tangential component of the magnetic field at the plane of the surface of the strong discontinuity without any change in its value.

Without considering the details of the rotational discontinuity generation due to the nonlinear processes in the magnetic field tube, let us deal with its interaction with the transition region approximated by a contact discontinuity.

It is known that an abrupt jump-like increase in the temperature of electrons and an abrupt decrease in the concentration of electrons exist inside a region of size 500 km (Gurzadian, 1984). Using the data obtained by Gabriel (1994), we suppose that the plasma density and the temperature obey the relation $n = \text{constant}/T$ for an abrupt change in temperature from 5×10^4 to 5×10^5 K.

The application of the model of the contact discontinuity to the transition region was reported only by Shibata (1996).

It is useful to note that a rotational discontinuity is well characterized by the angle φ at which it falls and the parameters of the unperturbed region before the discontinuity (Fig. 1). Also, for the rotational discontinuity a relation between a non-dimensional Mach number and the plasma parameter β will be valid:

$$\mathrm{M}_*^2 = \frac{2}{\gamma\beta}\sin(\varphi - \psi), \tag{4}$$

where φ is the angle at which it falls, β the parameter of plasma pressure and γ the polytrope index.

The numerical solution of the problem of the interaction of the solar rotational discontinuity A with the contact discontinuity CD = C in the transition region may be found on the basis of the laws of conservation (the conditions of dynamic correspondence) similar to the considerations of Grib and Pushkar (1992) when dealing with the oblique interactions of MHD strong discontinuities. In this case an oblique interaction of the plane-polarized rotational discontinuity with the contact discontinuity is reduced to the stationary self-similar MHD problem. The generalized polars are used in accordance with their use by Barmin and Pushkar (1990), when all the flow parameters after the new MHD shock and/or self-similar waves are found for definite initial conditions.

Thus, for the plasma parameter $\beta < 1$, for an angle $\psi = \mathrm{B_0C} = 30^\circ$ and for the angle between C and the X axis equal to 175°, we obtain

$$\underset{\rightarrow}{\mathrm{AC}} \rightarrow \underset{\leftarrow}{\mathrm{R_+}}\,\mathrm{AS_-C'}\underset{\rightarrow}{\mathrm{S_-}}\mathrm{AR_+},$$

where $\mathrm{R_+}$ is the fast rarefaction wave and $\mathrm{S_-}$ is the slow shock wave.

Therefore, a slow dissipative shock wave, directed to the solar corona, may appear as the result of the interaction of the rotational discontinuity with the transition region.

In the case when $\psi = 15^\circ$ we have a refracted fast shock wave.

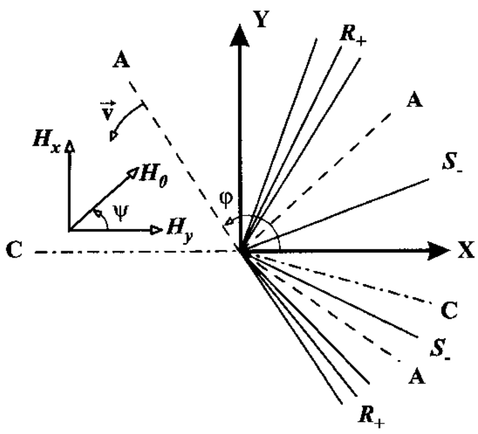

FIGURE 1 A schematic diagram of the interaction of the solar rotational discontinuity with the contact discontinuity in the transition region.

3 CONCLUSION

It is shown that solar shock waves heating the coronal plasma may appear as a result of the collision of the solar rotational discontinuity with the contact discontinuity in the transition region, providing a source for the dissipation of the magnetic field energy and causing spicules and explosive events, as described by Mariska (1992) and Perez et al. (1999).

It is useful to note that the rotational discontinuities appearing also as secondary discontinuities in the case of an oblique interaction between strong MHD discontinuities in the solar plasma indicate the solar activity. This statement correlates with the results of SOLTIP project discussed in 1996 in Beijing (Feng et al., 1998).

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